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Estimating greenhouse gas emissions using emission factors from the Sugarcane Development Company, Ahvaz, Iran

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Abstract

Background: Greenhouse gas (GHG) emissions are increasing worldwide. They have harmful effects on human health, animals, and plants and play a major role in global warming and acid rain.

Methods: This research investigated carbon dioxide (CO_2) and CH_4 emissions obtained from different parts of the Hakim Farabi, Dobal Khazaei, and Ramin factories which produce ethanol and yeast. Seasonal rates of CO_2 at the soil surface at the studied sites were estimated from measurements made on location and at intervals with manual chambers. This study aimed to assess the production rate of GHG emissions (CH_4, CO_2) in the sugar production units of Hakim Farabi, Dobal Khazaei, and Ramin factories.

Results: Mean concentrations of CO_2 and CH_4 emissions are respectively 279 500.207 and 3087.07 tons/year from the Hakim Farabi agro-industry, 106 985.24 and 1.14 tons/year at the Dobal Khazaei ethanol producing factory, and 124 766.17 and 1.93 tons/year at the Ramin leavening producing factory.

Conclusion: Sugar plant boilers and the burning of sugarcane contributed the most CO_2 and CH_4 emissions, respectively. Moreover, lime kilns and diesel generators showed the least carbon dioxide and methane emissions, respectively.

Keywords: Carbon Dioxide, Methane, Ethanol, Farms, Global Warming

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Introduction

Greenhouse gases (GHGs) cause a significant amount of pollution in the atmosphere (1). They are harmful to human health, animals, and plants, and they play a major role in global warming and acid rain (2). During recent decades, public concern has arisen regarding the presence of air pollutants both outdoors and indoors, and their potential to damage human health has increased (3,4). Carbon dioxide (CO_2) and CH_4 are the main GHGs today; CO_2 emissions from fossil fuels are the main cause of global warming (5,6). Other studies showing the importance of CO_2 and CH_4 rates in global warming have been conducted in some industrial and agricultural countries (7-11). The great development of the sugarcane and ethanol production industries, including agricultural industries and other technologies, seen in recent decades has created a need for recalculating the emission of pollutants and energy balances. Methane and CO_2 are the main emissions of the agricultural/industrial levels (12). In the last 10 years, atmospheric concentrations of CO_2 have increased by almost 40%, from a preindustrial concentration of approximately 280 ppmv (parts per million volume) to almost 384 ppmv in 2007 (13). Large reductions in GHG emissions are expected to prohibit serious climate destabilization, however, GHG emissions from fixed and transport sources are growing more quickly than other energy-using sectors and are predicted to increase GHG emissions by 80% between 2007 and 2030 (14). CH_4 is produced during the production and transport of coal, natural gas, oil, and other natural resources such as fertilizer and landfills with open-path technology and other anaerobic waste treatment systems (15,16). Municipal landfills are great resources of CH_4 emissions; in municipal solid waste landfills, CH_4 is about

30 times more potent as a heat-trapping gas (17). About 3.6% to 7.9% of natural gas released to the atmosphere is CH_4 gas (18). The main GHGs included SOx, NOx, PM, CO_2, and HCs, all of which cause global warming and increase atmospheric temperatures. Today, the proportion of CO_2 and CH_4 directly emitted by each country has been much discussed, have focused on CO_2 emissions, as the most important GHG. Specifically, emphasis has been placed on CO_2 emissions as the exhaust of fossil fuel combustion, cement and the other industrial manufactories, which is termed CO_2 here, referring to fossil carbon. Increasingly, CO_2 and CO emissions from land-use change and forestry (LUCF) are garnering much attention. However, it is not just CO_2 that is causing global warming; a suite of human activities resulting in the emission of GHGs is termed climate-altering pollutants (CAPs). Among GHGs, CO_2 emissions cause about one-half of total global warming (7). The resulting contrary health outcomes cause governments to work collectively with resolution to reduce and remove GHG emissions. What has been less widely understood, though, is that policies to decrease GHG emissions (climate change mitigation policies) could pave the way for great effects on the health of people in a society (8,19). GHGs in industry are emitted from two main sections. These emissions including direct and indirect emissions that are produced at the facility and occur off-site, respectively (20). After 10 years of an annual average growth rate of 4%, the years 2012 and 2013 showed a decrease to about 1%, also global CO_2 emissions abated 0.5% in 2014 to the record level in 2013. In 2014, the Environmental Protection Agency (EPA) reported that industry emissions accounted for approximately 21% of the total GHG emissions in the world (21). Carbon is the most abundant element in the production of sugarcane that can be changed to CO_2 and CH_4 pollution as the result of burning. Some fossil fuels are used in industry and agriculture; some bagasse, for example, is used as fuel in other parts, and a portion of the bagasse is used inside the factory as fuel for the boilers used in sugar production. The current study evaluated the emission factors of GHG emissions of (CO_2) and (CH_4) in the production of Hakim Farabi agriculture and industry, which includes raw sugar and sugarcane, and Dobal Khazaei and Ramin factories that produce alcohol and yeast. Industries, factories, and farms emit large quantities of CO_2 and CH_4 during the various stages of production. The main sources of CO_2 and CH_4 emissions are fuel-consuming equipment, such as boilers, lime kilns, diesel generators, electrical equipment in factories, and sugarcane burning for the elimination of waste; thus, CO_2 is emitted during the process of producing alcohol.

Methods

Description of the study area

This study was performed in Ahvaz city located in southwest Iran, which includes an estimated area of 220 km^2 and an estimated density of 4815.73 people per square kilometer. The climate in Ahvaz is tropical with a limited downfall period and an extended dry period lasting generally 9 months per year (22). One of the biggest industries in this city is the Hakim Farabi agro-industry, which is in southeastern Ahvaz, located on the Kilometer 35 Road of Ahvaz-Abadan. With the geographical coordinates of zone 39R, 267920.09 m E and 3426751.75 m N, this area has 12 thousand hectares of arable land. In addition, this complex has several units, including a sugar production unit with the capacity to produce 100 000 tons of sugar per year, the alcohol production units of Dobal Khazaei, and an agricultural part including 10 000 ha of arundinaceous farms. Figure 1 shows the location of the studied stations.

Energy input and GHG emissions

For this research, CO_2 and CH_4 emissions were obtained from different parts of the Hakim Farabi, Dobal Khazaei, and Ramin factories that produce ethanol and yeast. Sampling time and the number of samples were one year and 144, respectively. Seasonal rates of CO_2 at the soil surface at the sites were estimated from measurements made on location and at intervals with manual chambers. The soil CO_2 rate was measured continuously with six automatic chambers. The rate of CH_4 in the above yield was measured continuously using a micrometeorological gradient method. In addition, the emission and conversion factors were used for the CO_2 and CH_4 stack and emitted gasses from different sections such as boilers; field burners were vented to ambient air. One method for estimating CO_2 and CH_4 emissions is the ratio of energy output and input to GHG emissions, which demonstrates the quantity of CO_2 and CH_4 by measuring the concentrations of these gases in the fuel.

Results

The results of this study showed that CO_2 and CH_4 emissions from the Hakim Farabi agro-industry are 279 500.207 and 3087.07 tons/year, respectively, from the Dobal Khazaei ethanol producing factory are 106 985.24 and 1.14 tons/year, respectively, and from the leavening producing factory is 124 766.17 and 1.93 tons/year, respectively. Sugarcane is cultivated in an area of

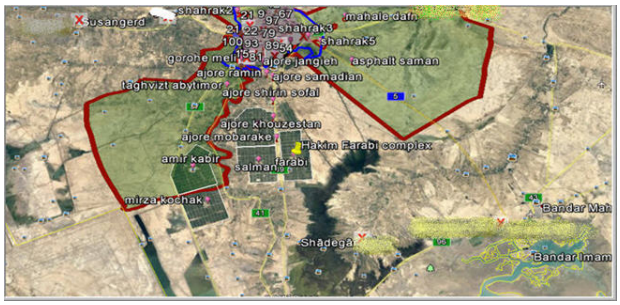


Figure 1. Locations of the studied stations.

Table 1. CO_2 and CH_4 emission factors in sugarcane factories

Emission resource	Gas	Emission factor	Unit	Reference
Sugarcane straw Burning in the field	CO_2	1.66	g/kg	CEPA (23)
	CH_4	2.7	g/kg	CEPA
Trash burning in the field	CO_2	1.3 – 1.4	kg/tones	EPA (24)
	CH_4	2.7	kg/tones	IPCC (24)
Boiler emission	CO_2	1891	g/m^3 fuel	CAPP (25)
	CH_4	0.03	g/m^3 fuel	CAPP
Limestone burning emission	CO_2	3.14	kg/m^3 fuel	Canada can met energy diversification research laboratory (26)
	CH_4	0.12	Ton CO_2/1000 m^3 fuel	CAPP
Diesel generator	CO_2	2.68	Kg CO_2/L fuel	SEIA (27)
	CH_4	0.13	g CH4/L fuel	Canada national inventory report

12 000 hectares in the Farabi farm. The main sources of GHG emissions in this complex are open burning in the field, boilers, limestone burning, diesel generators, and electrical equipment. Emission rates for the different parts were calculated using the following formula. Table 1 indicates the emission factor for CO_2 and CH_4 gases in sugarcane factories as different guidelines. Emission factor and emission rate are common and simple indices used to show GHG emissions. Table 2 indicates the CO_2 and CH_4 emission rates at different units of the Dobal Khazaei factory.

Emission rate = emission factor * fuel type (22)

The emission factors in different parts of the factory based on type of fuel are as follows:

Emission factor = Emission rate / Fuel type

Figure 2 shows the carbon dioxide and methane emission rates during harvest; this emission factor obtained from bagasse burning that occurred as open-field burning at the Hakim Farabi farm.

Dobal Khazaei factory is one of the main factories in the region. It produces the largest amounts of ethanol and leaven in the country. In this factory, there are 3 sources of CO_2 emissions (boilers, the ethanol unit, and electrical equipment) and two sources of CH_4 emissions (boilers and electrical equipment). Figure 3 shows a comparison of CO_2 and CH4 emission rates from different emission sources at the Hakim Farabi factory. Figure 4 shows the CO2 and CH4 emission rates at the Dobal Khazaei factory.

Methane and carbon dioxide emissions

Methane and carbon dioxide are emitted from different parts of the Hakim Farabi and Dobal Khazaei complexes, including the burning of sugarcane fields before harvest,

Table 2. CO_2 and CH_4 emission rates from Dobal Khazaei factory

Emission resource	Gas	Emission (ton/year)
Boiler (ethanol production)	CO_2	10892.16
	CH_4	0.20
Leaven production process	CO_2	14000
Boilers (Leaven production process)	CO_2	7412.72
	CH_4	0.14

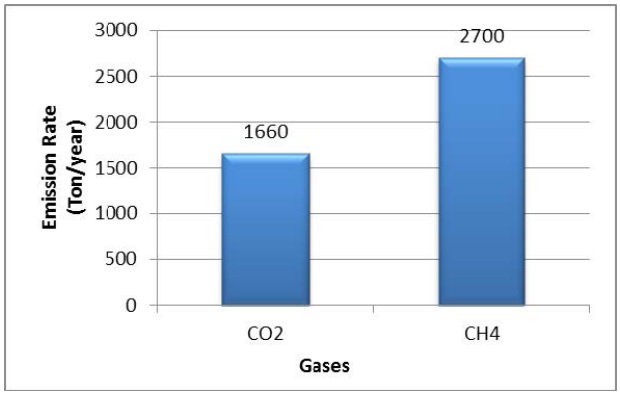
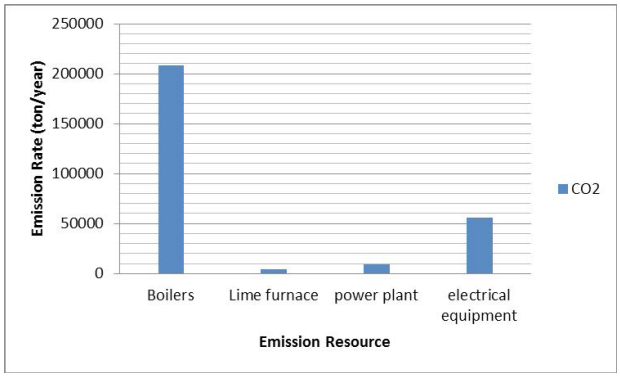


Figure 2. Open-field burning at Hakim Farabi farm.



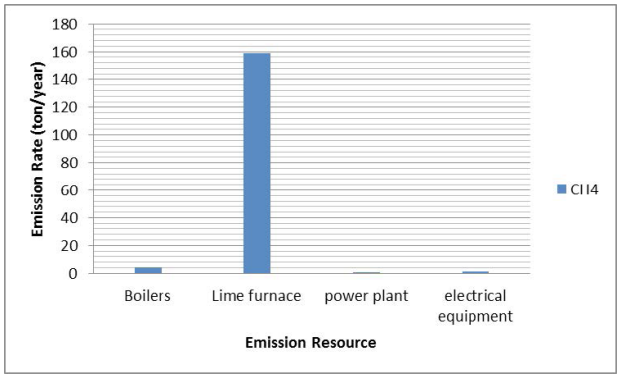


Figure 3. Comparison of CO_2 and CH_4 emissions from different sources at Hakim Farabi Sugar factory

using stillage as fertilizer, boilers, and burning ethanol in ethanol engines. Results of this study indicate the emission factor for CH_4 and CO_2 in Hakim Farabi farm. During the burning of sugarcane trash in the field, CH_4 is the main gas produced and emitted; CO_2 emissions are insignificant. Therefore, the bulk of CH_4 emissions are produced in field by trash burning, whereas CO_2 emissions resulting from open burning in the field are related to bagasse and cane waste. Figure 5 shows the comparison of CO_2 and CH_4 emissions from different sources. A recent study that analyzed emission factors for sugarcane and simulated burning in a wind tunnel indicated that GHG emissions were 0.32 kg/t (dry fuel) in the case of a spreading fire and 0.59 kg/t (dry fuel) for fire in a pile. In transient or disturbed boiler processes, CH_4 emissions are produced only from unburnt organics.

Discussion

In this study, GHG emissions from five main factory sources were investigated, including the sugarcane farm, boilers, limestone burning, diesel generators, and electrical equipment. The Farabi cane crop was transferred from the farm to the Farabi, Dobal Khazaei, and Ramin factories to become the final products such as ethanol and sugarcane. Therefore, sugarcane mills produce sugar, ethanol, Leaven, which are splatted and sent to respond to market needs. Straw and sugarcane that are cut and burned on the Hakim Farabi farm produce the greatest amounts of CO_2 and CH_4 emissions. In addition, bagasse, the residue of sugarcane sap dewatered from sugarcane, is combusted in sugar factories to produce steam and electricity. Nguyen and Gheewala showed in their study that the methane emission rate from sugarcane burning is 3.5 kg/ton. They also revealed that open burning on the farm caused a CH_4 emission rate of 2.2 kg/ton. Their results were obtained by the emission factor (28). The Hakim Farabi and Dobal Khazaei factories are major producers of sugar, leaven, and ethanol, and their activities produce a large quantity of CO_2 and CH_4 emissions. Ordinarily, GHG emissions are produced in winter, which is the harvest season. The GHGs emissions from these factories along with particulate matter (PM) are considered synergistic agents. The California Environmental Protection Agency revealed that the CO_2 and CH_4 emission rates from the open burning of sugarcane for the production of ethanol are 315.973 and 514.1 g/ton, respectively (29), but in the current study, CO2 and CH4 emission rates of 1660 and 2700 g/ton were determined (Figure 2). Boilers are another part of the factories that release high concentrations of CO_2 and CH_4 emissions into the atmosphere. Boilers, lime furnaces, diesel generators, and electrical equipment are internal units in the Hakim Farabi Complex And are used in the production of sugar and ethanol. The GHG emissions in these processes are caused by the internal burner. This unit of the factory uses natural gas and gasoline; therefore, the emission and energy rates related to gasoline are affected by the class of the crude oil, the petroleum refinery configuration, and

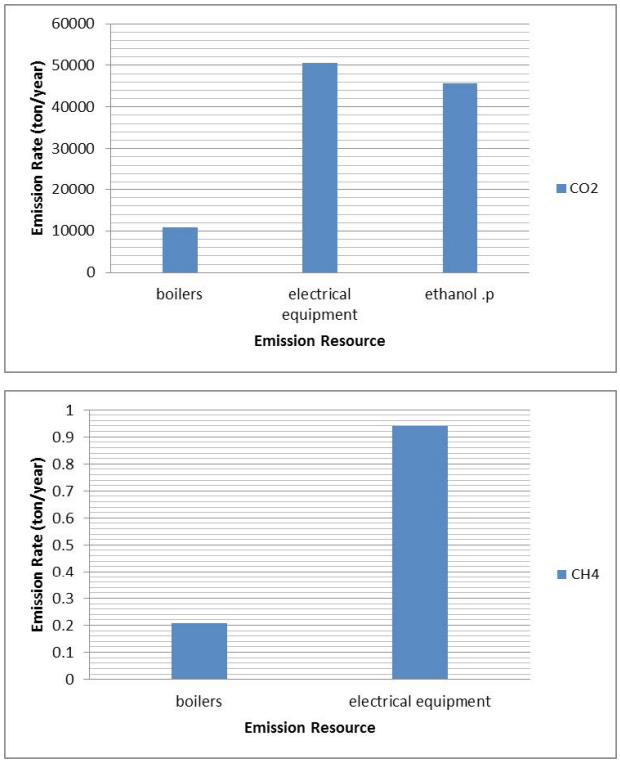


Figure 4. Comparison of CO_2 and CH_4 emissions from different sources at Dobal Khazaei factory

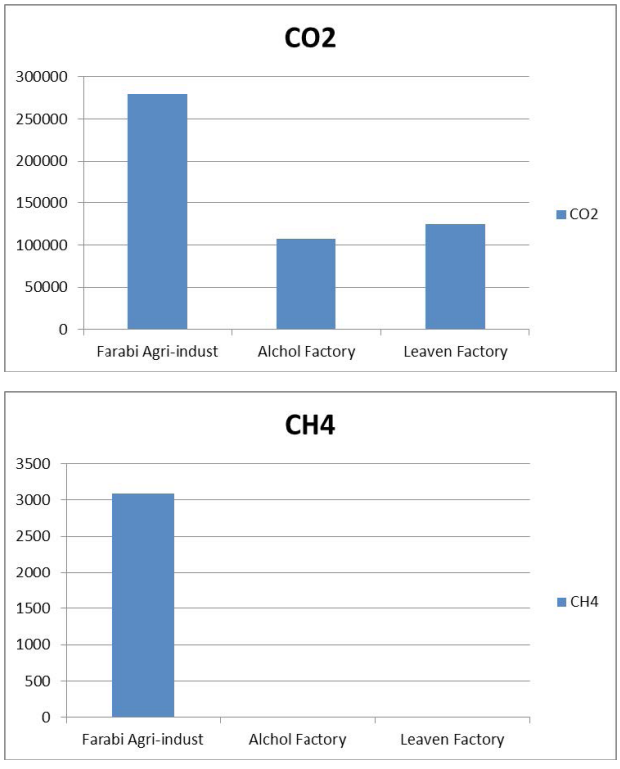


Figure 5. Comparison of CO_2 and CH_4 emissions from different sources in the whole complex

such factors as natural gas, petrol, and gasoline quality (11). The lime furnace uses natural gas, and therefore produces a high amount of CH_4. The power plant unit is one of the main parts of the Hakim Farabi complex. It uses six diesel generators to supply electricity to the entire Hakim Farabi complex. In this unit, the use of gasoline fuel could not be determined as local reliable documents were not available. Thus, international consolidated data about energy consumption and GHG emissions in the production of oil-derived fuels was used in this study. The electrical equipment is another main unit in the Hakim Farabi factory. This unit supplies electrical energy for the entire Hakim Farabi complex.

Total bagasse production is almost 1129222 tons/year (2014) at 50% moisture. It is the sum of bagasse which percentage of bagasse will be lost in different ways, and this is used as fuel in some industries such as paper pulp and food industries. However, the main part of bagasse is used in sugar mills as an energy resource to produce sugar or ethanol. Also some of bagasse are used to produce sugar and ethanol. The bagasse to sugar ratio is 1:1, and the bagasse to ethanol ratio is 0.5:1.

Sugarcane farming correlates with a significant amount of GHG emissions such as CO_2 and CH_4, from both upstream processes such as fertilizer production and from the field itself. The nitrogen in bagasse (i.e. straw) on the farm is also the N in fertilizer and emits N_2O. Open field burning was done in farm, by physical harvesting of sugarcane, and transportation logistics. These two activities are the main GHG emission sources in the sugarcane ethanol life cycle. In the last decade, mechanical harvesting increased the speed of operations. This technology also increased fuel consumption by 20%; however, the use of bigger equipment and new technology is replacing these methods. Automatic harvesting will increase to 50% in the next 8 years (10). However, mechanical harvesting will increase GHG emissions in the atmosphere. Moreover, an increase in green cane reaping will produce a huge volume of trash. This could increase GHG emissions due to open burning in the field. Most boilers do not have wet scrubbers, and CH_4 emissions have not been reported. The most significant pollutants emitted by bagasse boilers are CO_2 and PM, which can travel long distances in the atmosphere and be transferred to Ahvaz city atmosphere. Due to the higher volume of gases emitted from this agro-industry complex, it is suggested that this factory should use scrubbers and filters to control gases and use biofilters to remove gases through the use of microorganisms.

Conclusion

The Hakim Farabi, Dobal Khazaei, and Ramin are the most important sugar and ethanol factories in Iran, and they release a great amount of GHG emissions into the atmosphere. In these factories, GHG emissions come from five main sources: the sugarcane farm boilers, limestone burning, diesel generators, and electrical equipment. In these factories, straw and bagasse are burned in the field, and open burning released significant concentrations of CO_2 and CH_4 into the atmosphere. Ordinarily, GHG emissions are produced in winter, which is the harvest season. The GHG emissions from these factories along with PMs are considered synergistic agents. The emission rates for the different parts of the factories were calculated. The results showed that in the Hakim Farabi factory, boiler emissions, electrical equipment, diesel generator, limestone burning emissions, sugarcane straw burning in the field, and trash burning in the field released the highest concentrations of CO_2, respectively. Furthermore, sugarcane straw burning and trash burning in the field produced the biggest percentage of methane emissions. In open burning, the CH_4 emissions are greater than the CO_2 emissions. In the Dobal Khazaei factory, electrical equipment, ethanol, and boilers released the highest concentrations of CO_2 into the atmosphere. Also, the electrical equipment produced the highest rate of CH_4 emissions into the atmosphere.

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Ethical issues

It is confirmed that this manuscript is the original work of the authors. It has not been published, nor is it under review in another journal, and it is not being submitted for publication elsewhere.

Competing interests

The authors declare that they have no competing interests.

Authors' contribution

All authors contributed equally and participated in the collection, analysis, and interpretation of the data. All authors critically reviewed, refined, and approved the manuscript.

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